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DEVELOPMENT OF A UNIQUE MOBILE INTEGRATED SUPPORT SYSTEM FOR TACTICAL ELECTRONICS

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Rome Air Development Center
Air Force Systems Command
Griffiss Air Force Base, New York

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DEVELOPMENT OF A UNIQUE MOBILE INTEGRATED SUPPORT SYSTEM FOR TACTICAL ELECTRONICS

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DE-65-7

FOREWORD

The Mobile Integrated Support System (MISS) Project was developed entirely in the house under discretionary funds (DE-65-7) of the Chief Scientist of Rome Air Development Center. Design, fabrication, and test efforts were initiated in January 1965 and concluded in September 1968.

The authors wish to acknowledge the valuable assistance of Robert D. Merrill.

The week this report was ready for printing, we were informed that Dynastar Laboratories had decided to terminate future development work on its 150 HP diesel engine. Technical problems encountered were greater than could be solved in the near future. Therefore, our recommendation for any production version must be modified to include the need to locate or develop an engine meeting the critical size, weight, and fuel consumption requirements.

This technical report has been reviewed and is approved.

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ABSTRACT

Present tactical ground electronic equipment systems are too heavy. The support system required to transport and to power an electronic package is usually two to three times the weight of the electronic package. Parts of the support system, such as the truck, cannot be helicopter-lifted, thereby restricting or eliminating movement of the electronic package after helicopter movement. Moreover, system volume for air lift is too large. The ratio of the volume of the support system to the electronic package is at least two-to-one. Excessive numbers of cargo aircraft are required because of the bulk weight of the support items. Mobility cannot be added to a system as an afterthought, but must be considered with and as a part of the over-all system design. Designing for the specific tactical requirements and integrating the functions of the supporting equipment, wherever possible, will reduce system weight, aircraft support requirements, and set-up time. This report describes such a support system, the "Mobile Integrated Support System (MISS)," designed for transporting an S-141 type shelter package and compares it with the conventional means of transporting this electronic package.

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SECTION I

INTRODUCTION

Tactical ground electronic systems must be transported by several methods. Imagine that the conventional system is located somewhere in the United States and must be delivered to a place anywhere in the world. Therefore, it may have to be flown by C-130 aircraft, transported over road or cross-country, flown by helicopter, and, at the operational location, must be positioned quickly for optimum siting and setup.

Need for improvement in tactical ground electronic equipment mobility has been expressed many times in requirements, presentations, and operational plans, but little advancement has been made. Continual progress is being made in decreasing the weight and volume of the electronic equipment, but often this reduction is offset by a need for increased electronic capability, resulting in no net reduction in package size or weight.

The objective of this program was to provide a better lightweight system of transporting and powering tactical electronic equipment. Specific objectives were to minimize the time required for handling and to improve the over-all mobility.

Such a system, called the Mobile Integrated Support System (MISS), has been designed and developed at RADC and fabricated in the Griffiss Air Force Base Fabrication facilities.

SECTION II

GENERAL DESCRIPTION OF MOBILE INTEGRATED SUPPORT SYSTEM

Figure 1 shows an artist's concept of the Mobile Integrated Support System. It is composed primarily of two sections: the main front power section which attaches to the front of the S-141 equipment shelter and a rear section which attaches to the rear of the shelter. The forward or powered section houses a lightweight, 100 hp diesel engine which drives a hydraulic pump, producing oil flow and pressure for the hydraulic motors in each of the four wheels. The diesel engine also drives a 32kw, 400 Hz generator to provide electrical power for operation of the equipment in the package. The system can raise the package from a ground level to a road height, or lower the package to the ground for operation. Goals were to provide a support system weighing 4,000 lbs., capable of being lifted by helicopter, able to travel up to 45 mph on the highway, travel cross-country, climb a 60 percent grade slope, provide 32kw 400 Hz of electrical power, reduce volume so that two complete systems will fit in one C-130 aircraft, and limit setup time to no more than 10 minutes.

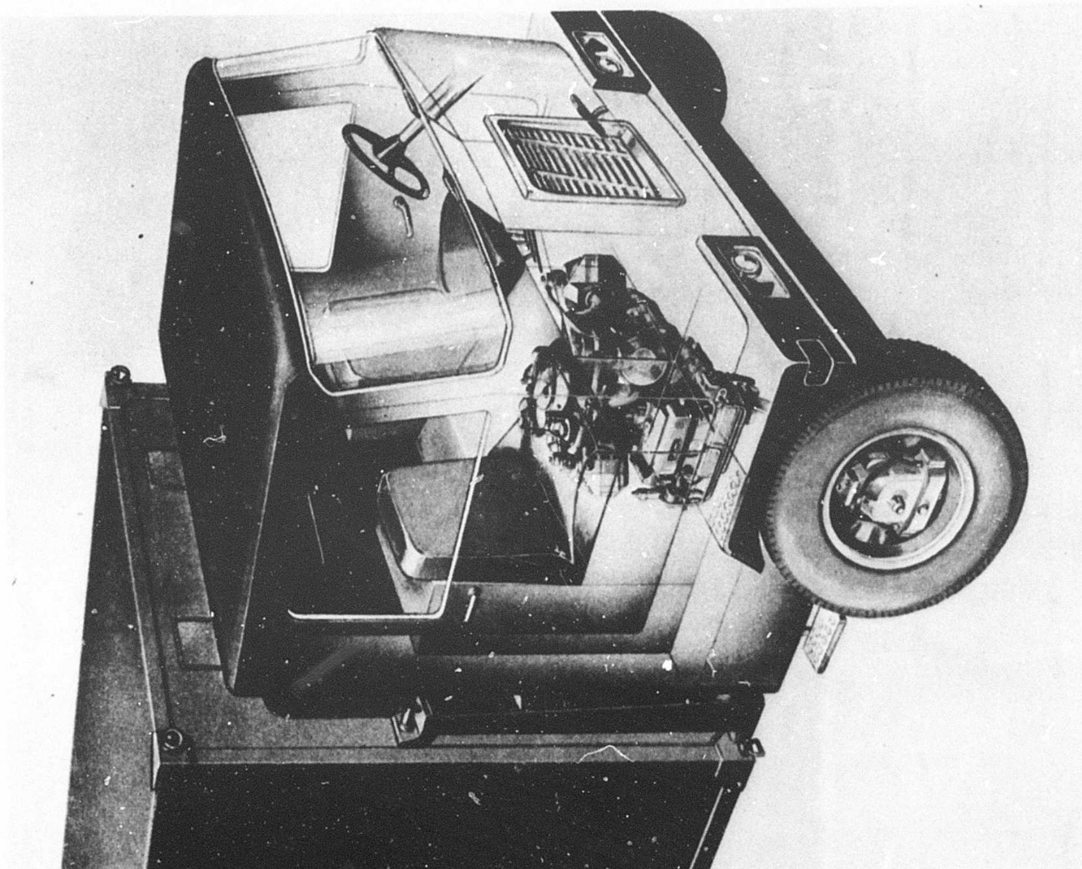


Figure 1. Artist's Concept of MISS

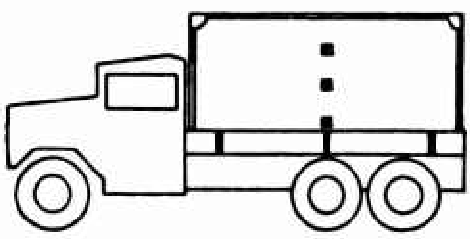
SECTION III

ANALYSIS OF CONVENTIONAL TRANSPORT

From Table 1, consider transporting a conventional system in an M-35 truck. This is a one-package system containing an electronic shelter weighing 4, 000 lbs. A truck weighing 12, 600 lbs. is required to transport this shelter. For the purposes of this comparison, a lightweight 450 lb. turbine-driven generator will be used which is configured to be transported within the package. A grip hoist device, weighing about 200 lbs., will be needed to remove the package from the truck. This results in a total system weight of 17, 250 lbs. Two helicopters are required to transport only the electronic equipment package and the power generating equipment. At the operational location there is no mobility with this system, since the package cannot be repositioned once it is set down. One C-130 aircraft is required to transport the complete system including the truck. Four men need approximately 45 minutes to set up this system, including removing the package from the truck and the power from the package, and hooking up the power for operation.

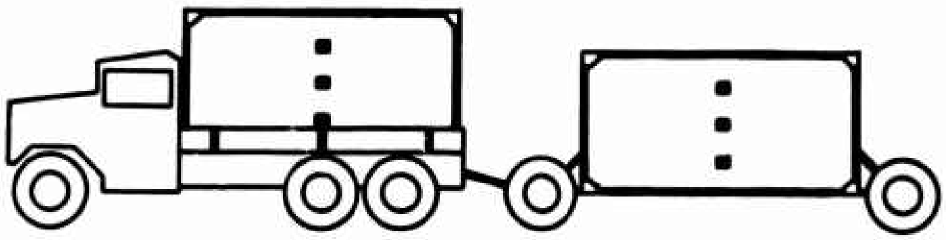
A two-package system, as shown in Table 2, gives a little better weight advantage but is still heavy. It still requires the handling device to remove the package from the truck, the same turbine generator in the package, and an undercarriage weighing

TABLE 1. CONVENTIONAL TRANSPORT - ONE PACKAGE



WEIGHT		HANDLING REQ'D.		
M-35 TRUCK	12,600 LBS	2—HELICOPTERS		(NO MOB)
ELECTRONIC PKG	4,000 LBS	1—C-130 AIRCRAFT		
TURBINE GEN	450 LBS	4—MEN	SET-UP TIME	45 MIN
HANDLING DEVICE	200 LBS			
TOTAL	17,250 LBS.			

TABLE 2. CONVENTIONAL TRANSPORT - TWO PACKAGES



WEIGHT		HANDLING REQ'D.		
M-35 TRUCK	12,600 LBS.	3—HELICOPTERS		(NO MOB.)
ELECTRONIC PKG'S.	8,000 LBS.	1½—C-130 AIRCRAFT		
HANDLING DEVICE	200 LBS.	4—MEN	SET-UP TIME	60 MIN.
TURBINE GEN.	450 LBS.			
UNDERCARRIAGE	2100 LBS.			
TOTAL	23,350 LBS.			

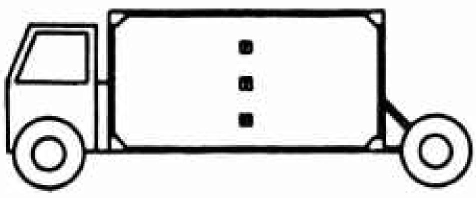
2,100 lbs. The total weight of this two-package system is 23,350 lbs. Three helicopters are required to transport just the two electronic packages and the power generating equipment, but, again, there is no mobility at the operational location. The space in 1 and 1/2 C-130 cargo aircraft are required to transport the electronic equipment, the power, and the truck. Four men need approximately one hour to set this equipment up for operation.

SECTION IV

ANALYSIS OF AN INTEGRATED SYSTEM APPROACH

The MISS (Table 3) would provide the following advantages in weight and handling capability. With MISS transporting the same 4,000 lb electronic equipment package, the total system weighs 8,000 lbs. Since power is already part of the MISS system, there is no need for an additional power package. Two helicopters can lift this system - one for the electronic package, and one for the support system. Full mobility would be provided at the operational location as well as the capability to reposition the packages as needed. One-half the cargo space of the C-130 aircraft is needed to transport the complete system, MISS and the electronic package, and two men can set up this system in approximately 10 minutes, including the removal of the package from the support system and hooking up the power for generating electricity.

TABLE 3. INTEGRATED SYSTEM - ONE PACKAGE



WEIGHT		HANDLING REQ'D.		
ELECTRONIC PKG.	4000 LBS	2—HELICOPTERS		(FULL MOB)
SUPPORT SYSTEM (INCL. POWER)	4000 LBS.	½—C-130 AIRCRAFT		
TOTAL	8000 LBS	2—MEN	SET-UP TIME	10 MIN
TO TRANSPORT TWO-PACKAGES				
DOUBLE WEIGHTS				

If two electronic packages are required to be transported, two MISS units would be necessary for full mobility doubling the weight to 16,000 lbs for two electronic packages.

Table 4 summarizes weight and transport requirements. Notice that the integrated system weight is less than half the conventional one-package system. Helicopter requirements are the same, but the Mobile Integrated Support System has full mobility at the operational location. Half of the C-130 aircraft is used for transport and set-up time is reduced to 10 minutes by two men.

TABLE 4. COMPARISON OF CONVENTIONAL VS INTEGRATED SYSTEM

	TRANSPORTING			
	ONE PACKAGE		TWO PACKAGES	
	CONV.	INT.	CONV.	INT.
WEIGHT TOTAL	17,250	8,000	23,350 (LM)	16,000
HELICOPTERS REQ'D.	2 (NM)	2 (FM)	3 (NM)	3 (LM)
C-130 AIRCRAFT REQ'D.	1	½	1½	1
SET-UP TIME (MIN.)	45 (4 MEN)	10 (2 MEN)	60 (4 MEN)	10 (4 MEN)

NM — NO MOBILITY

LM — LIMITED MOBILITY

FM — FULL MOBILITY

With two electronic packages, the integrated system weighs about two-thirds as much as the conventional system and uses the same number of helicopters, but mobility is limited in this case since only one MISS system is transported. Therefore, the packages would be re-positioned serially. One C-130 aircraft is required compared to one and one-half for the conventional system, and set-up time is only 10 minutes by four men as compared to 60 minutes by four men with the conventional system.

SECTION V

EXPERIMENTAL MODEL

An experimental model was designed and fabricated to demonstrate the MISS concept as shown in Figure 2. This model has been tested to a limited degree and has met most of the goals. The shelter can be loaded and unloaded within the 10 minute set-up time. A road speed of 32 mph has been achieved - not quite the goal of 45 mph. Calculations in Section I of the Appendix compares the theoretical horsepower required for a speed of 45 mph and the actual horsepower applied to obtain the 32 mph road speed. Due to the power losses in the hydraulic system and the marginal prime power package, maximum design speeds were not reached. The model has climbed a sandy 40 percent slope. The desired support-to-equipment weight ratio of 1:1 was not attained. But the 1.5:1 ratio attained compares favorably with the 3.3:1 ratio for a conventional system. The model provided electrical power, and volume was reduced such that two MISS models and electronic packages will fit in one C-130 aircraft.

The prime power unit, Figure 3, is a developmental model of a Dynaster diesel engine weighing 425 lbs. It is 26-1/2 in. from side to side and front to back, and 21 in. high from the fly wheel to the top of the unit. This engine has proved quite satisfactory. It has a fuel consumption rate of approximately 0.48 lbs per brake hp hour, comparing favorably with diesel engines now in use. The slower speed, heavier, conventional diesels have a specific fuel consumption rate of about 0.38 lbs per brake hp hour. Rates for gasoline engines are approximately 0.9 lbs per brake hp hour, and for turbines close to 2 lbs per brake hp hour. The developmental engine is rated 100 brake hp, but the maximum usable horsepower for MISS was 80. The maximum design speed of 45 mph was, therefore, not attained.

The diesel engine drives the main hydraulic pump through a multiple output transmission, as shown in Figure 4. The transmission, in turn, drives the main pump and a control pump to provide the necessary hydraulic power for the system. When generating electrical power, the engine is cut off and the transmission gear is shifted to drive the alternator. The generated power was regulated well within a ± 2 1/2 percent frequency tolerance, meeting the general requirements for ground electronic equipment (MIL-E-4158D).

All of the wheels (Figure 5) of the support system are powered. Each hydraulic motor is mounted in an aluminum hub to which the tire and rim are attached; the motor drives the rim of the hub through a 7.35 to 1 gear reduction. The hub has been designed so that the hydraulic motor may be removed for service or repair by simply

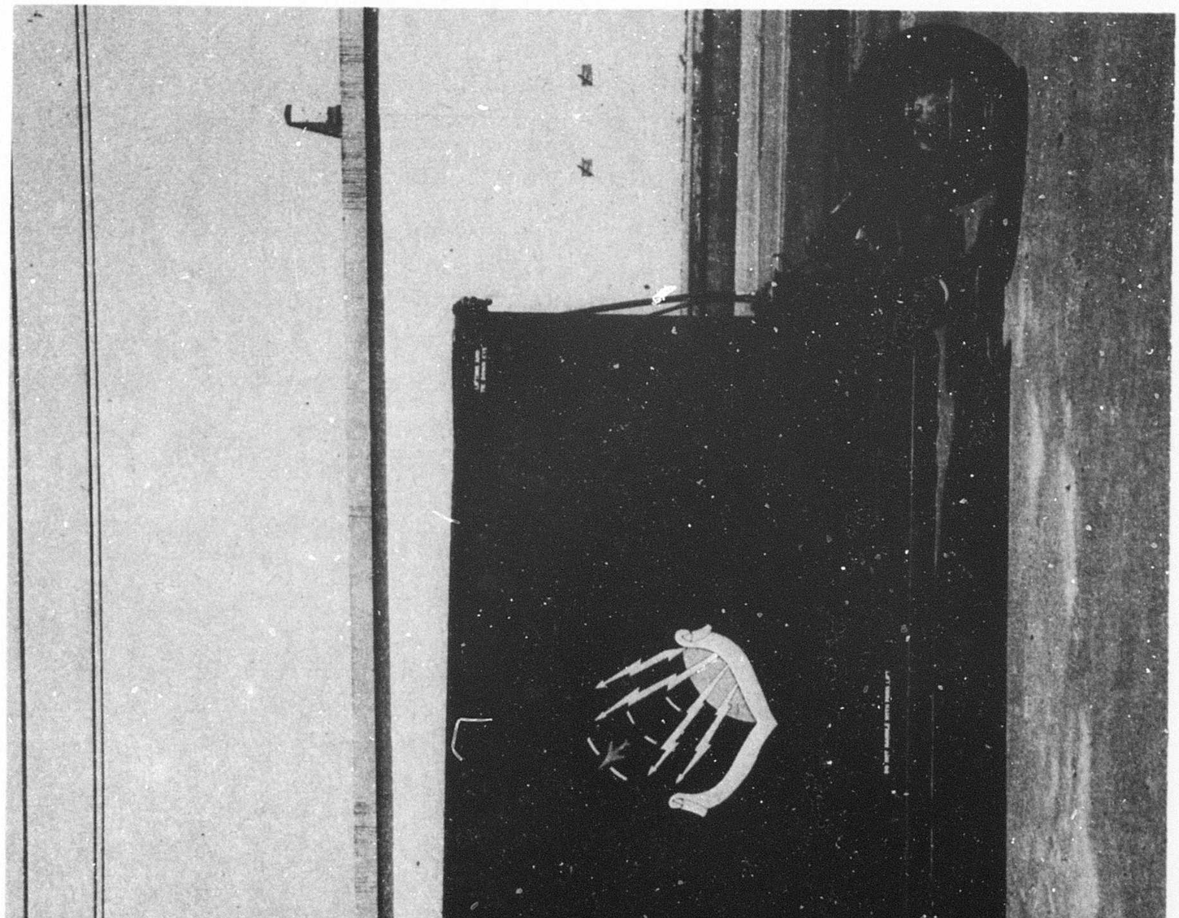


Figure 2. Experimental Model

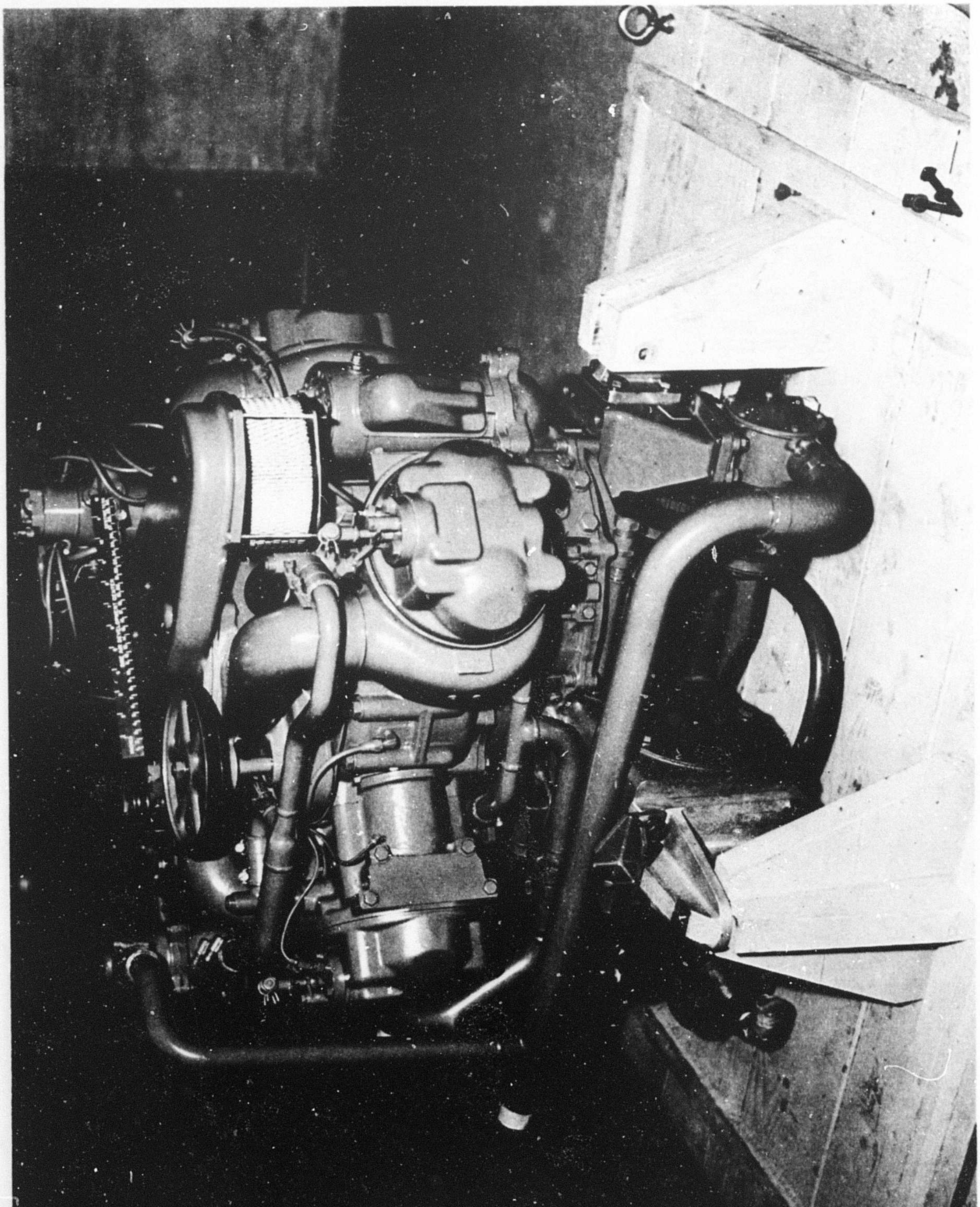


Figure 3. 100 HP Diesel Engine

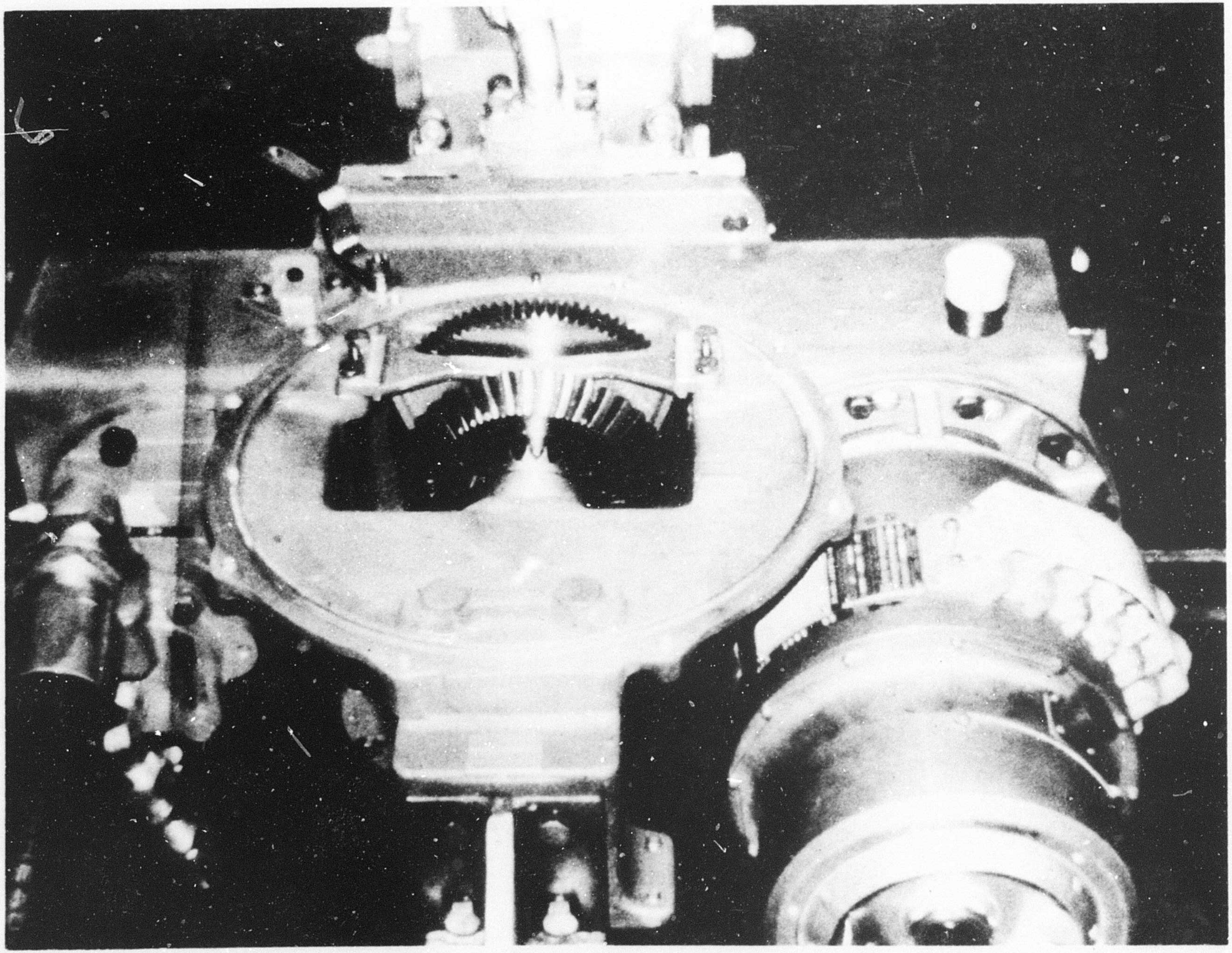


Figure 4. Multiple Output Transmission

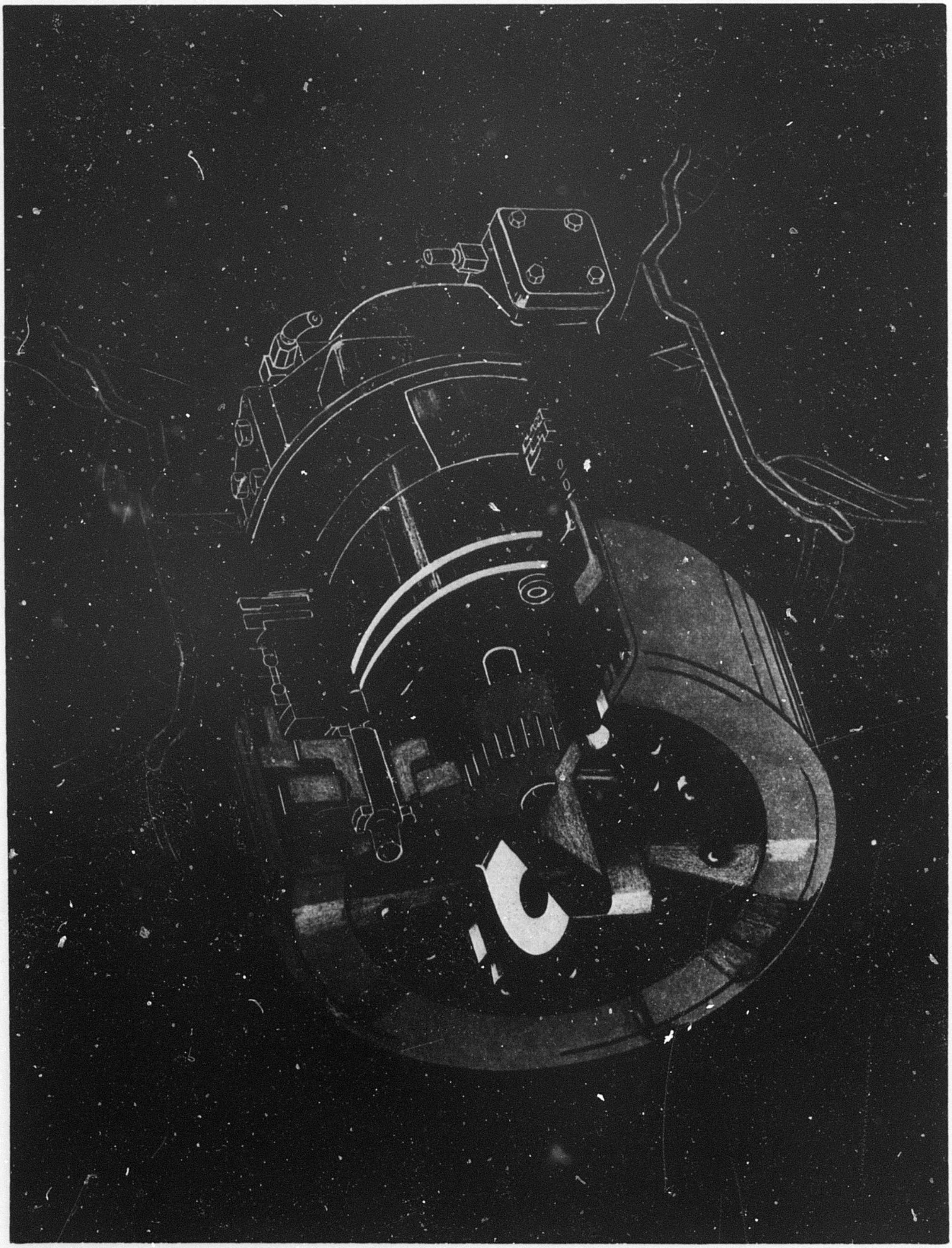


Figure 5. Wheel Assembly

detaching the hydraulic lines and the mounting bolts without jacking or other disassembly. The hub also contains a disc brake system, which serves as a parking brake and as a back-up for the dynamic braking system. An automatic wear compensating device has been incorporated in the disc brake system.

The Mobile Integrated Support System was road tested over dirt roads at Griffiss Air Force Base. The air spring suspension system, designed to give protection to the electronic equipment, gave a very satisfactory ride while driving over rutty and hilly roads.

A 40 percent grade sandy slope was used on the test course. Maximum power was not required in negotiating this slope. This is illustrated by the calculations in Section II of the Appendix. There was ample excess power to climb a 60 percent incline, especially on a concrete surface as is normally done at the Aberdeen Proving Ground, Maryland.

SUMMARY OF ACCOMPLISHMENTS FOR EXPERIMENTAL MODEL

GOAL	RESULT
10 minute set-up time	Accomplished
Maximum speed 45 mph	32 mph
60% grade climbing capability	40% (maximum available for test)
Support-to-equipment weight ratio 1:1	1.5:1
Volume reduction - two MISS models within one C-130 aircraft	Accomplished
Generate 32 kw of power	Accomplished

SECTION VI

DESCRIPTION OF THE UNLOADING OPERATION

To unload the electronic package, the hydraulic lines running along the top of the shelter are first separated from the cab and rear assembly by self-sealing quick-disconnects. Next, the cab support wheels are released hydraulically, dropped to the ground, and then placed on a spline to lock them in place.

Two bolts at the front torque tube are removed and the rear of the shelter is lowered almost to the ground. At this point, the front of the shelter is raised off the torque tube and lowered to the ground by a pair of hydraulic cylinders mounted to the rear of the cab. A second pair is used to lower the rear assembly. Figure 6 shows the shelter detached from the support system. The rear assembly is essentially a standard mobilizer section modified with two driving wheels, each containing a hydraulic motor and with a castered wheel that allows raising the weight of the torque tube from the ground. Thus the entire assembly can be moved by two men.

The rear assembly, detached from the shelter, is wheeled to the rear of the cab. Standard castings are provided with the mobilizer to attach the front and rear sections together. Two castings, one on each side, fasten the upper part of the torque tube together, and castings for the lower hooks, make it one unit. The support wheels are now raised and locked up so that MISS can be driven as a complete road unit. When it is hooked together in this manner (see Figure 7), it may be driven back to a staging area to pick up and position a second package.

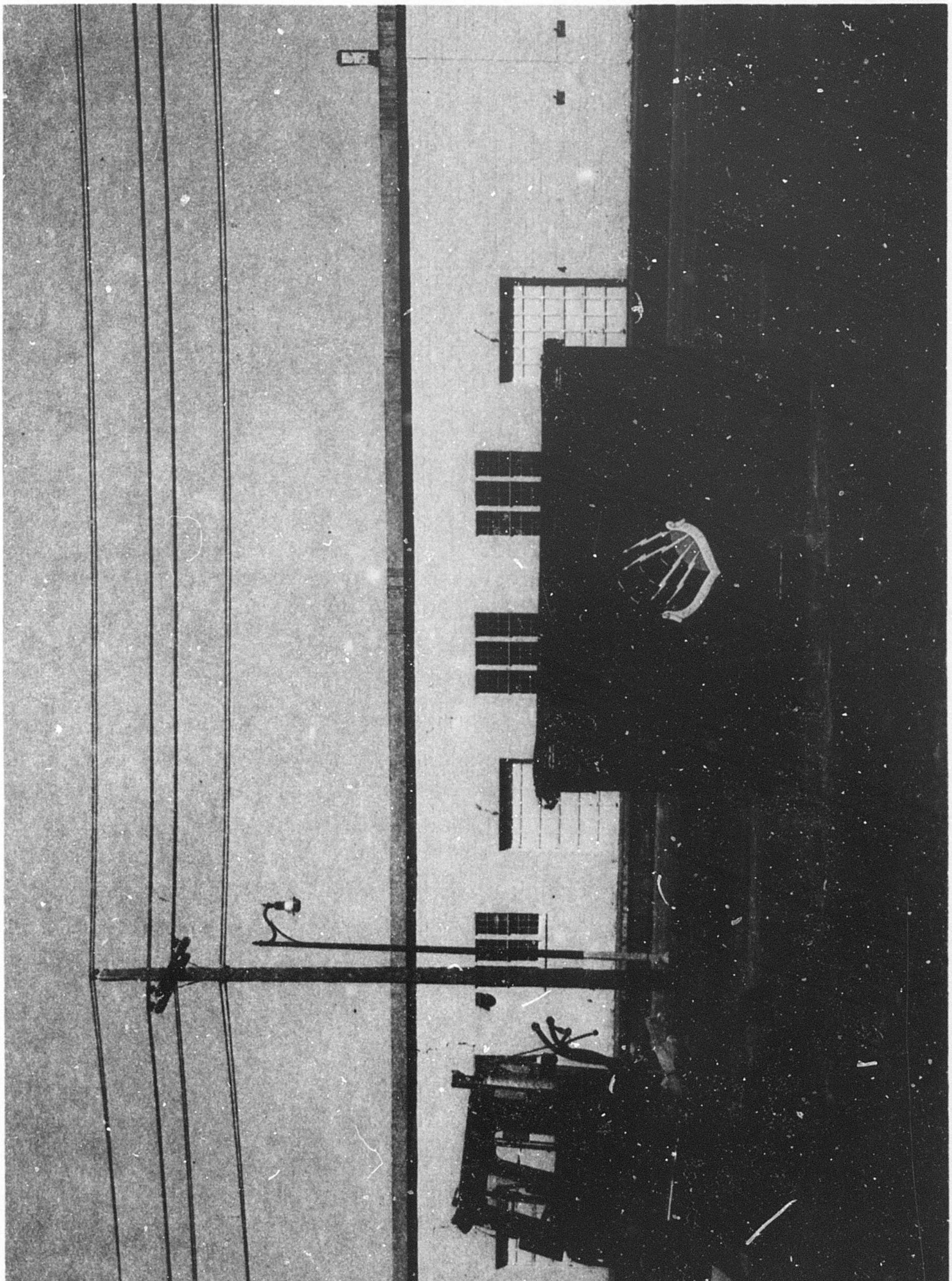


Figure 6. MISS-Shelter Lowered

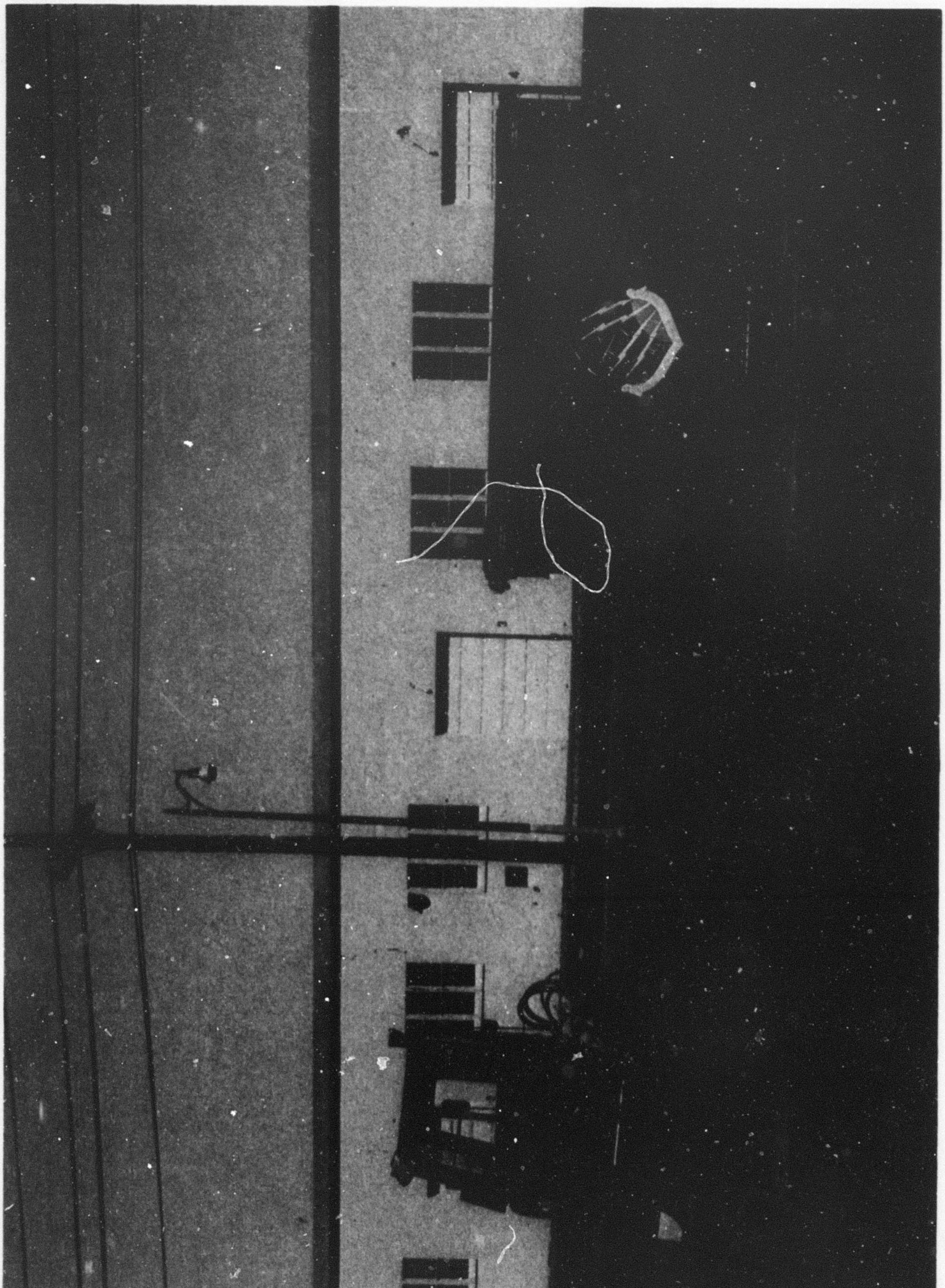


Figure 7. MISS-Cab Unit

SECTION VII

RECOMMENDATIONS

The experience gained from this experimental model has provided a basis for modifications in any production unit. The completely hydraulic system, in our opinion, is too sophisticated for field use, because it is quite susceptible to dirt. Any dirt in the system could easily score moving surfaces within the pump, motors, and valves, rapidly affecting their ability to function. It is also quite sensitive to temperature changes, and control circuitry requires considerable adjustment to maintain in good running condition. Therefore, a mechanical-hydraulic drive combination should be incorporated in the production version. Since the hydraulic drive is extremely good at low speeds and high torque, it should be retained on the rear wheels for cross-country, hill-climbing conditions. The front section could be mechanically driven through a standard type transmission/differential combination which would automatically cut in the rear wheel drive at low speeds and cut it out at higher speeds.

Prior reference has been made to insufficient power in the present system. A 150 hp engine is recommended for the production unit. The Dynastar engine will be available in this size with very little penalty in additional weight and size. The 150 hp engine would be approximately 30" from side to side and front to back, and reduced to 18" in height. The weight of the present engine is 425 lbs, but this does not include an oil cooler, an oil sump, or water pump, so that the actual weight of the present engine with its components would be nearer 500 lbs. The production engine, which does include the oil cooler, the oil sump, and the water pump, is estimated at 600 lbs.

The third change suggested is to generate 60 kw 400 Hz of electrical power rather than the 32 kw. The availability of a 150 hp engine permits the use of a larger generator. Figure 8 shows the present generator. The 60 kw would increase the length by only 3 inches, to an over-all length of 16 inches; would increase the weight by approximately 50 lbs, to a total weight of 135 lbs; and would not change the outer diameter or the mounting face.

It is also recommended that the maximum payload of the electronic package for road travel be raised from 4,000 to 5,000 lbs, a realistic weight limit transportable by MISS without a severe penalty on the size and weight. Although the 4,000 lb. weight limit is needed for helicopter lift, the road weight limit is normally higher because other equipments are transported in the package when traveling on the road. The top speed could exceed 50 mph with the proposed mechanical-hydraulic combination system.

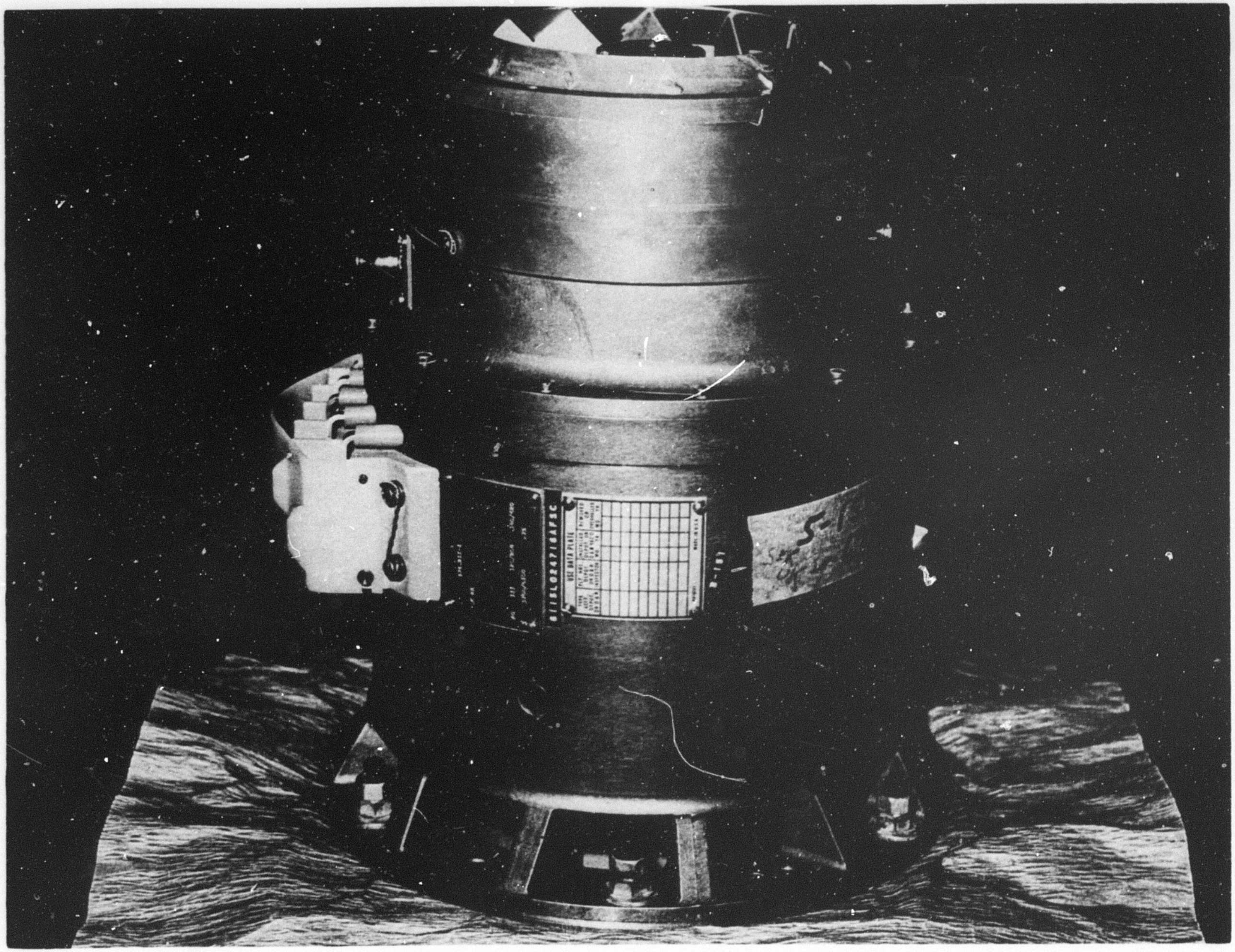


Figure 8. 32 kw 400 Hz Generator

SECTION VIII

COMPARISON: MISS VS CONVENTIONAL APPROACH FOR THE AN/TPS-43 RADAR

MISS can be compared with an actual system, such as the AN/TPS-43 radar. Figure 9 shows that the AN/TPS-43 radar is composed of two packages: the electronic equipment shelter and the antenna pallet. In addition, to operate this system a 60 kw power pallet package, mounted on a truck, is required. Table 5 tabulates weight and handling requirements of the AN/TPS-43 radar.

Three helicopters are required to lift the two equipment packages and power pallet, but again, without mobility at the operational location. Two C-130's could transport the entire system as listed. To remove the packages from the trucks and to set up power involves six men for a period of 20 minutes.

Figures 10 and 11 show the AN/TPS-43 transported and deployed by the MISS system. There would now be two packages, the electronic equipment package and the antenna pallet package. Since the antenna pallet package has the standard mobilizer attachments, there is no problem transporting this with the MISS system. At the operational site, the second MISS unit would become a 60 kw back-up power.

TABLE 5. AN/TPS-43 CONVENTIONAL

WEIGHT		HANDLING REQUIRED	
M-35 Truck	12,600 lbs	3-Helicopters	(No. Mob.)
Equipment Shelter	3,500 lbs	2 C-130 Aircraft	
Antenna Pallet Pkg	3,500 lbs	6-Men Set-up Time	20 min.
Undercarriage	2,100 lbs		
	21,700 lbs		
Power			
2-60 KW Turbine Gen	2,000 lbs		
1-Pallet	700 lbs		
1 M-35 Truck	12,600 lbs		
	15,300		
TOTAL	37,000 lbs		

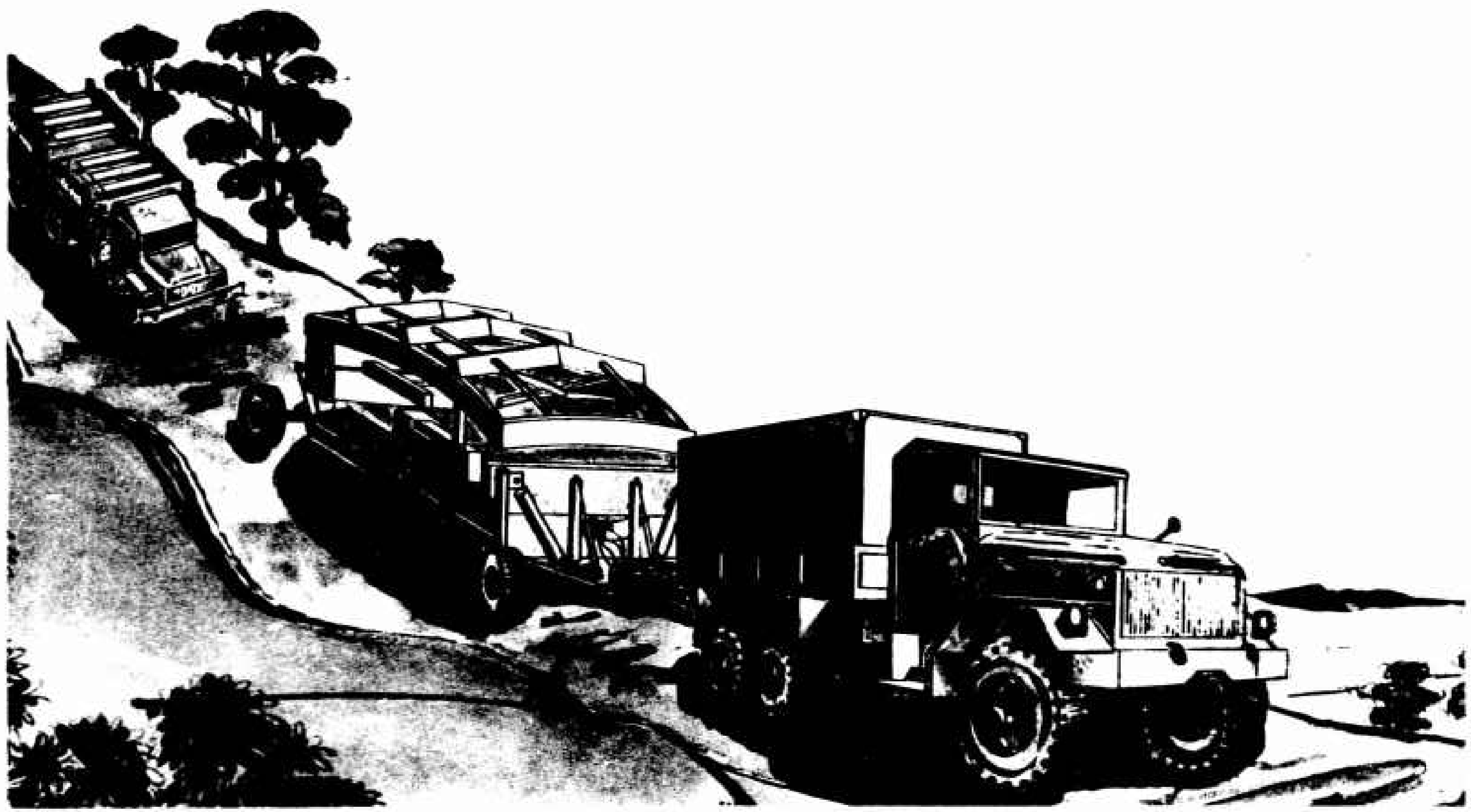


Figure 9. AN/TPS-43 Conventional

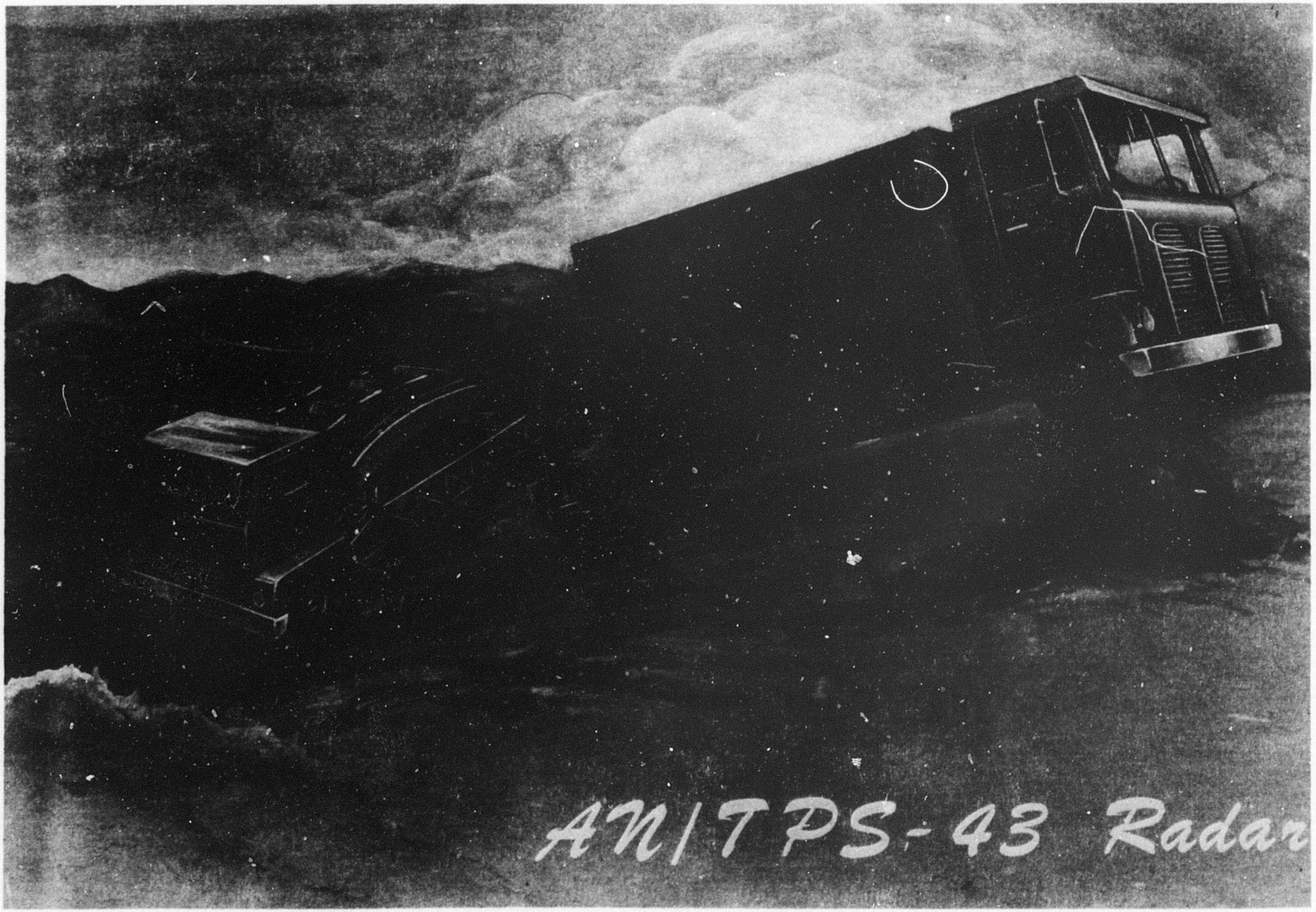


Figure 10. MISS and AN/TPS-43

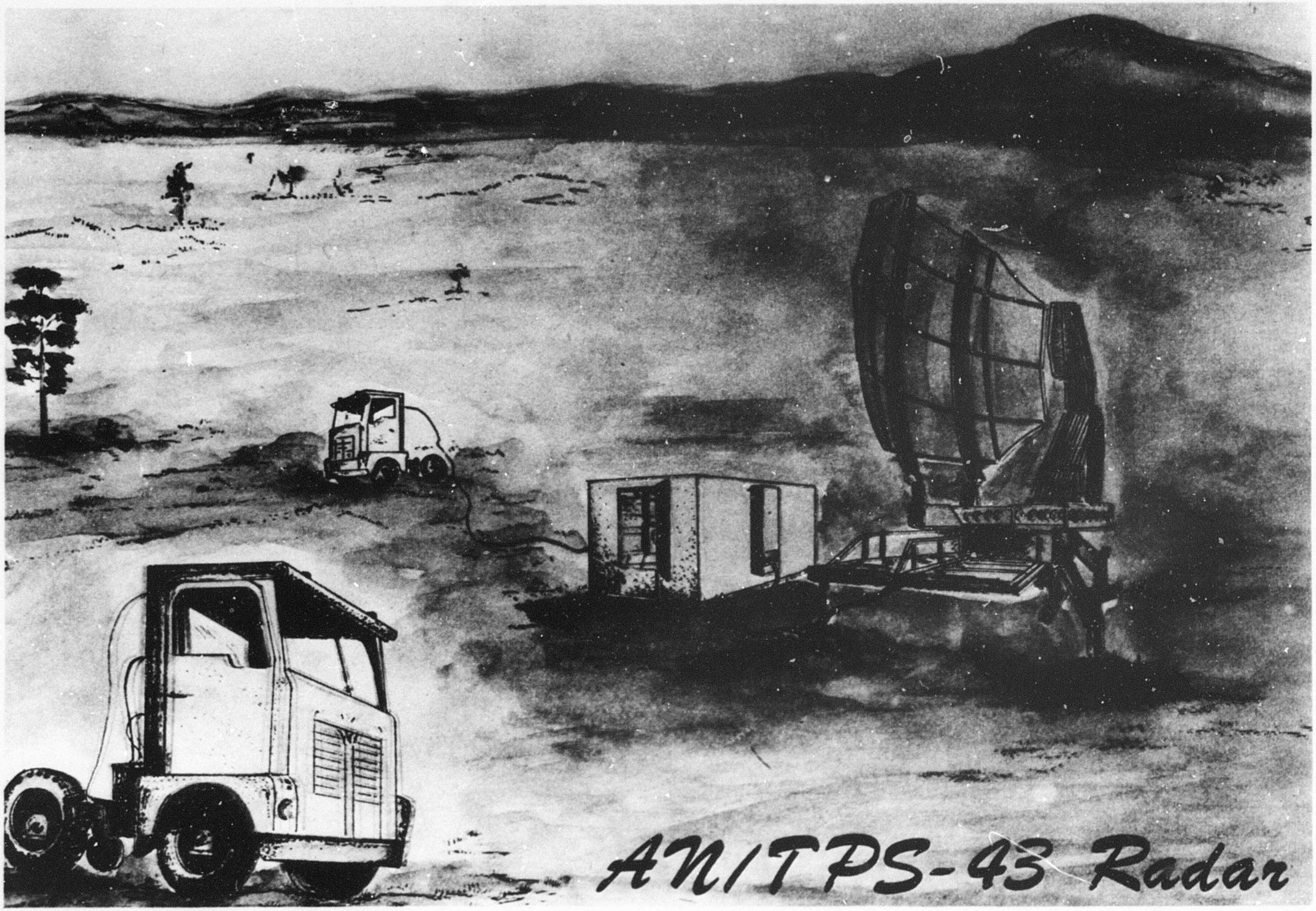


Figure 11. MISS and AN/TPS-43 Deployed

Table 6 shows the weight of the MISS/AN/TPS-43 combination totals 15,000 lbs for the complete package. Four helicopters are required to lift this complete system, providing full mobility at the site to reposition the packages as needed. If back-up power at the remote site is not needed, only three helicopters can be used and still retain the mobility to reposition these packages. One C-130 aircraft can lift the complete system. Four men could set it up in 10 minutes, or two men in 20 minutes.

Generally, from Table 7, it is seen that MISS is half the weight of the conventional AN/TPS-43 system. Four helicopters are required if it is desired to have back-up power and full mobility at the operational location. There are three helicopters in both cases when back-up power is not taken with the MISS unit, but the MISS provides some limited mobility. Only one C-130 aircraft is required, compared to two for the conventional system, four men can set up the equipment in 10 minutes less time and set-up time can be reduced by 10 minutes with an accompanying reduction of two men in crew size.

TABLE 6. MISS AND AN/TPS-43

WEIGHT		HANDLING REQUIRED
2 Support Systems	8,000 lbs	4-Helicopter (with backup power) (Full Mob.)
Equipment Shelter	3,500 lbs	3-Helicopter (60 KW power) (Part Mob.)
Antenna Pallet Pkg	3,500 lbs	1 C-130 Aircraft
TOTAL	15,000 lbs	4-Men Set-up Time 10 min.
		2-Men Set-up Time 20 min.

TABLE 7. COMPARISON OF CONVENTIONAL vs MISS FOR AN/TPS-43

	MISS AN/TPS-43		AN/TPS-43 CONV.
WEIGHT TOTAL (LBS)	15,000		37,000
HELICOPTERS REQ'D.	4 WITH BACK-UP POWER(FM) 3 NO BACK-UP POWER (LM)		3 (N M)
C-130 AIRCRAFT REQ'D.	1		2
SET-UP TIME (MIN.)	10 (4 MEN)	20 (2 MEN)	20 (6 MEN)

NM - NO MOBILITY

LM - LIMITED MOBILITY

FM - FULL MOBILITY

SECTION IX

SUMMARY

Summarizing, the advantages of this support system are apparent. It can significantly improve the over-all mobility of an electronic system because it simplifies aircraft loading without additional equipment; it retains this mobility after helicopter transport; it is 50 percent lighter in weight than most of our conventional systems; the set-up time is much shorter with less manpower required.

Moreover, Table 8 summarizes the fuel consumption rates for several generator sets. The most significant savings occur when considering fuel weight within a 24-hour period. A diesel prime mover, as used in MISS, could provide a savings of nearly 1 ton per day in refueling requirements as compared to turbine driven power.

The system is sufficiently versatile to provide mobility and generate electrical power for any kind of standard electronic package, communications or radar. Any S-141 shelter or S-280 shelter, with standard attachments, can be transported.

TABLE 8. FUEL REQUIREMENTS AT RATED LOAD (60 kw)

	FUEL CONSUMPTION			
PRIME POWER	GAL/HR	LB/24 HRS	GAL/24HRS	COST/24HRS
TURBINE (EMU-30)	19.0	2964	456	$45.60
DIESEL (MB-17)	5.8	904.8	139.2	13.92
DIESEL (MISS)	6.7	1071	164.8	16.48

APPENDIX

SYMBOLS

A	=	Cab frontal area, sq ft
Ca	=	Coefficient of air resistance, $lb\text{-}sec^2\text{-}ft^{-4}$
Dm	=	Motor displacement, in^3 per rev
F	=	Tractive force, lb
f	=	coefficient of rolling resistance
Nm	=	Motor speed, rpm
P	=	Power consumption of hydraulic pump, hp
p	=	Pump discharge pressure, psi
Δpm	=	Pressure drop across motor, psi
Qp	=	Pump discharge flow, gpm
r	=	Rolling radius, in
Ra	=	Air resistance, lb
Rg	=	Grade resistance, lb
Rr	=	Rolling resistance, lb
Tm	=	Motor torque output, lb-in
Vr	=	Vehicle speed relative to air, mph
W	=	Vehicle weight, lb
η_p	=	Total pump efficiency
η_m	=	Motor volumetric efficiency
γ	=	Wheel gear ratio
θ	=	Slope angle, deg

1. <u>Power required for 45 mph speed on a 0% grade</u>

a. Calculations based on manufacturer's performance curves:

$$Qp = \frac{2\ Dm\ Nm}{\eta_m\ 231} \qquad \text{(Motor displacement of } 6° = 2.23\ \frac{in^3}{rev}\text{)}$$

$$= \frac{2\ (2.23)\ (3830)}{(.90)\ (231)} = 82\ \text{gpm}$$

Tractive force (F) required principally to overcome rolling and air resistance (headwind excluded).

$$F = Rr + Ra \qquad A = 46.6\ \text{sq. ft.}$$

$$= fW + CaA \left(\frac{Vr}{10}\right)^2 \qquad f = .012\ \text{(asphalt road)}$$

$$= (.012)\ (8000) + (.26)\ (46.6)\ (20.2)$$

$$= 96 + 244.5 = 340.5\ \text{lbs}$$

$$Tm = \frac{F\ r}{2\gamma}$$

$$= \frac{(340.5)\ (14.5)}{(2)\ (7.35)} = 336\ \text{lb-in} \qquad \text{(only two front motors driving)}$$

$$\Delta pm = \frac{2\ \pi\ Tm}{Dm} = \frac{2\ \pi\ (336)}{2.23} = 947\ \text{psi}$$

Power consumption of main system pump at engine speed of 2500 RPM.

$$p = 1150\ \text{psi} \qquad (947 + \text{estimated line losses})$$

$$P = \frac{Qp\ p}{1714\ \eta_p} = \frac{(82)\ (1150)}{(1714)\ (.90)} = 61.3\ \text{hp}$$

Power consumption of auxiliary pumps at engine speed of 2500 RPM.

Control Pump, Pc (Gear type - dual volume output)

$$Pc = P_1 + P_2 = \frac{(Qp_1\ p_1 + Qp_2\ p_2)}{1741\ \eta_p} \qquad \begin{array}{l} P_1 = \text{power of 1st output} \\ P_2 = \text{power of 2nd output} \end{array}$$

$$= \frac{(12.3)\ (450) + (15.8)\ (1000)}{(1714)\ (.85)} = 14.7\ \text{hp}$$

Fan Drive Pump, Pf (Vane type)

$$Pf = \frac{Qp\ p}{1714 \times \eta_p}$$

$$= \frac{(20)\ (1000)}{1714 \times .90} = 12.9 \text{ hp}$$

Total horsepower = Main pump power + auxiliary pump power

= 61.3 + (14.7 + 12.9)

= 88.9 hp

This compares to available 100 brake horsepower at an engine speed of 2500 RPM.

b. Calculations based on test results at maximum road speed of 32 mph - 1900 engine RPM:

$$Qp = \frac{2\ Dm\ Nm}{\eta_m\ (231)}$$

(Two front motors driving at a motor displacement of 6°, volumetric efficiency was in the order of 85%)

$$= \frac{2(2.23)\ (2645)}{(.85)\ (231)}$$

= 60.1 gpm

Power consumption of main system pump at engine speed of 1900 RPM.

P = 1500 psi (average value)

$$P = \frac{Qp\ p}{1714\ \eta_p} = \frac{(60.1)\ (1500)}{(1714)\ (.90)} = 58.4 \text{ hp}$$

Power consumption of auxiliary pumps at an engine speed of 1900 RPM.

Control Pump, Pc

$$Pc = \frac{(Qp_1\ p_1 + Qp_2\ p_2)}{1714\ \eta_p}$$

$$= \frac{(8.9)\ (400) + (11.4)\ (950)}{(1714)\ (.85)} = 9.9 \text{ hp}$$

Fan Drive Pump, Pf

$$Pf = \frac{Qp\ p}{1714\ \eta_p}$$

$$= \frac{(15)\ (900)}{(1714)\ (.90)} = 8.8 \text{ hp}$$

Total horsepower = Main system pump + auxiliary pumps = P + (Pc + Pf)

$$= 58.4 + (9.9 + 8.8)$$

$$= 77.1 \text{ hp}$$

This compares to an available 84 brake horsepower at 1900 engine RPM. Engine torque output (230 lb-ft) peaks at this point. At greater engine speeds pump torque demands exceeded engine torque output capability.

II. <u>Power required for 60% slope - 2 mph</u>

a. Calculations based on manufacturer's performance curves:

At low speeds air resistance is considered negligible and at constant speed tractive force balances only rolling and grade resistance.

$$F = Rr + Rg$$

$$= fW + W \sin \theta \qquad f = .06 \text{ (medium hard surface)}$$

$$= (.06)\ (8000) + (8000) \sin 31°$$

$$= 4600 \text{ lbs}$$

$$Tm = \frac{F\ r}{4\ \gamma} \qquad \text{(four motors driving)}$$

$$= \frac{(4600)\ (14.5)}{(4)\ (7.35)} = 2261 \text{ lb-in}$$

$$\Delta pm = \frac{2\pi\ Tm}{Dm} = \frac{2\pi\ (2261)}{7.24} = 1961 \text{ psi}$$

Pump delivery at 2 mph

$$Qp = \frac{4\ Nm\ Dm}{231\ \eta v} = \frac{(4)\ (171)\ (7.24)}{(231)\ (.90)} = 23.8 \text{ gpm}$$

Power consumption of main system pump at engine speed of 1900 RPM.

$p = 2000$ psi (includes estimated line losses)

$$P = \frac{Q\,p}{1714\,\eta_p} = \frac{(23.8)\,(2000)}{(1714)\,(.90)} = 30.9 \text{ hp}$$

Total horsepower = Main system pump + auxiliary pumps = P + (Pc + Pf)

= 30.9 + (9.9 + 8.8)

= 49.6 hp

b. **Calculations based on test results taken at 2 mph on a 40% grade dirt road.**

Power consumption of main system pump at engine speed of 1400 RPM.

$p = 1700$ psi (average value)

$$P = \frac{Q\,p}{1714\,\eta_p} = \frac{(23.8)\,(1700)}{(1714)\,(.90)} = 26.3 \text{ hp}$$

Power consumption of auxiliary pumps at an engine speed of 1400 RPM.

Control Pump

$$Pc = \frac{(Q)_1\,P_1 + (Q)_2\,P_2)}{1714\,\eta_p} = \frac{(6.9)\,(350) + (8.9)\,(850)}{(1714)\,(.85)} = 6.9 \text{ hp}$$

Fan Drive Pump

$$Pf = \frac{Q\,p}{1714\,\eta_p} = \frac{(10.9)\,(700)}{(1714)\,(.90)} = 4.9 \text{ hp}$$

Total Horsepower = Main system pump + auxiliary pumps = P + (Pc + Pf)

= 26.3 + (6.9 + 4.9)

= 38.1 hp

This compares to an available 58 brake horsepower at 1400 engine RPM.

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13. ABSTRACT

Present tactical ground electronic equipment systems are too heavy. The support system required to transport and to power an electronic package is usually two to three times the weight of the electronic package. Parts of the support system, such as the truck, cannot be helicopter lifted, thereby restricting or eliminating movement of the electronic package after helicopter movement. Moreover, system volume for air lift is too large. The ratio of the volume of the support system to the electronic package is at least two to one. Excessive numbers of cargo aircraft are required because of the bulk and weight of the support items Mobility cannot be added to a system as an afterthought, but must be considered with and as a part of the over-all system design. Designing for the specific tactical requirements and integrating the functions of the supporting equipment, wherever possible, will reduce system weight, support aircraft requirements, and set-up time. This paper describes such a support system, called the "Mobile Integrated Support System (MISS)," designed for transporting an S-141 type shelter package and compares it with the conventional means of transporting this electronic package.

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